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OPTICAL OBSERVATIONS OF THE FIELD OF GRB 970111

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Abstract

B, V and R optical photometry performed on the field of the GRB 970111 soon after its detection by BeppoSAX is presented. No remarkable optical object is found inside the corrected error box. The optical counterpart of an X–ray and radio source and a suspected red variable (probably an eclipsing binary) have been detected inside the field of GRB 970111.

1 Introduction

GRB 970111 was detected as a three–peaked Gamma–Ray Burst (hereafter GRB) on January 11, 1997 by the Wide Field Camera of the X–ray satellite BeppoSAX (Costa et al. 1997). This was the second GRB event (after GRB 960720; Piro et al. 1996) ever observed by BeppoSAX; the coordinates of the burst were: $\alpha = 15^{\rm h}28^{\rm m}24^{\rm s}$, $\delta = 19°40'.0$ (equinox 2000.0; error box radius = 10'). Soon after, Butler et al. (1997) reported that two faint X–ray sources, hereafter labelled as 'a' and 'b', are present in the field of GRB 970111. According to Guarnieri et al. (1997a), no object has shown remarkable variations in the optical, neither in the field of GRB 970111 nor in the error boxes of the two X–ray sources. Then, Hurley et al. (1997a) reduced the error box of GRB 970111 and found that only BeppoSAX source 'a' lies within it. Source 'a' appears to be also an optical (Guarnieri et al. 1997b, Kulkarni et al., 1997) and radio source (Frail et al. 1997a). This error box was one of the smallest ever given for a GRB, making it suitable for the search for optical counterparts. The width of the error box did not allow us to image it in one single frame, so we focused our attention on the X–ray sources, in particular on source 'a'. Unfortunately, due to a misalignment of the Wide Field Cameras of BeppoSAX (in't Zand et al. 1997), the error box reported by Costa et al. (1997) had to be shifted ∼3' from its previous position; then, Hurley et al. (1997b) gave a new error box, seven times smaller than the former and located in its southern part.

In this paper we present an optical photometric analysis mainly concerning the northern and central parts of the GRB 970111 former error box (Hurley et al. 1997a), observed from January 14 (i.e. ∼65 hours after the burst) to March 12. Section 2 will briefly describe the reduction and calibration techniques, while Section 3 will present and analyse the results.

2 The observations

The frames have been obtained with the 1.5-meter telescope (equipped with the BFOSC instrumentation) of the Bologna Astronomical Observatory on January 14, 15, 17 and 31, on February 14, 17 and 18, and on March 5 and 12, 1997. B, V and R filters were employed. We used long (15 to 75 minutes) exposure times to reach limiting magnitudes ranging from ∼20.5 to ∼22. B, V and R images of the PG 1047+003 sequence (Landolt 1992) were also obtained in order to calibrate the field of GRB 970111.

A comparison among frames acquired on the same night in different bands and performed with a simple FORTRAN code allowed us to determine the $B-V$, $V-R$ and/or $B-R$ colors of most stars within the former GRB 970111 field. The same procedure was applied to frames collected on different nights but in the same filter in order to search for the variable stars of the field. This double cross–correlation allowed the selection of interesting object which will be presented and discussed in the next Section.

3 Data analysis and discussion

No object inside the various fields showed any remarkable blue excess (we found that no $B-V$ was lower than 0.5 and no $V-R$ was lower than 0.2). These fields are at fairly high galactic latitude ($b^{\rm II} = 53°$); so, the interstellar absorption, and thus the $B-V$ color excess, should not be high. Thus, the values of the color indices quoted above should not be very different from the unabsorbed ones. Therefore, the prime selection rule has been the light variability, with particular attention to the objects, inside the part of the corrected error box contained in our images of January 14 and 17, which showed a decline in their luminosity. None of them presented a decrease of more than 0.3 mag in R, thus confirming the results by Castro–Tirado et al. (1997).

A frame containing the whole GRB 970111 corrected error box (Fig. 1a), taken on March 5 under photometric sky conditions, shows no object down to $R \sim 22$ at the position of the radio source reported by Galama et al. (1997). Actually, we see that this field is rich in galaxies, as we found about 30–40 galaxies with $R < 21$ in the GRB 970111 error box reported by Costa et al. (1997).

Two objects of the northern part of the extended error box (Hurley et al. 1997a) have particularly drawn our attention: the optical counterpart (object 1 in Fig. 1b) of ROSAT X–ray source 'a' (Butler et al. 1997) and of the radio source VLA J1528.7+1945 (Frail et al. 1997a) and a long–term red variable (object 2 in Fig. 1b).

As regards object 1, it is almost certainly the optical counterpart of BeppoSAX source 'a' and of radio source VLA 1528.7+1945. Its position has been computed by

means of the Digitized Sky Survey (hereafter DSS) and its coordinates coincide, within the errors, with the position of the radio source given by Frail et al. (1997a). Object 1 appears as a $R = 20.6 \pm 0.1$ object, while it is barely visible on the V frame of January 31. It is instead invisible in the B frame of the same night ($B > 21$). On the Palomar plates, this object is undetectable in B and is about at the same R luminosity level stated above. On February 18, its B and V magnitudes were 21.7 ± 0.1 and 21.0 ± 0.1, respectively, while its R magnitude was at about the same value of the January observations. This implies that its colors are $B - V = 0.7$ and $V - R = 0.4$. The March data confirm these figures.

The object has been resolved by Kulkarni et al. (1997) into two moderately redshifted galaxies separated by ∼2".5. Indeed, it is asymmetrical and seems to be formed by at least two (but probably four; see Fig. 1b) objects, with the two brighter ones coinciding with the galaxies S1 and S2 reported by Kulkarni et al. (1997).

Fig. 1. a Corrected error box of GRB 970111 (Hurley et al. 1997b). The field, obtained in the R band on March 5, covers an area of 9'×9' and has a limiting magnitude of ∼22. **b** Northern part of the former error box of GRB 970111 as indicated by Hurley et al. (1997a). This R frame (area: 4'.5×4'.5), obtained also on March 5, has the same orientation and limiting magnitude of that in Fig. 1a. See text for further details on objects 1 and 2 indicated here.

Concerning the other interesting object, i.e. object 2, after a quick–look comparison between the field and the DSS, we noticed on our R frames the clear presence of a star which was barely visible on the DSS (whose limiting magnitude is $R \sim 20.5$). The star is also practically invisible in the Palomar Sky Survey red plates and absent in the blue ones (limiting magnitude ∼21 for both). From the DSS we deduced the

coordinates of this object: $\alpha = 15^{\rm h}\ 28^{\rm m}\ 45^{\rm s}$; $\delta = +19^\circ\ 47'\ 15''$ (equinox 2000.0), with a conservative error of $\pm 5''$ for both values. No variable object within a circle of radius 10' and centered on these coordinates is mentioned in the SIMBAD database.

The star, on January 15, 1997, was at $R = 19.90 \pm 0.05$, thus showing a variation of more than a magnitude with respect to the Palomar red plates (April 1950), while on January 17 the R magnitude was 19.93 ± 0.05. On January 31 its magnitude in the R band decreased and was found to be 19.80 ± 0.05. During the same night, its $V - R$ color index was 0.54 (see also Masetti et al. 1997).

The February observations reveal that this object has a $B = 21.8 \pm 0.1$ and a V magnitude in agreement with the values of January 31. Its $B-V$ color index is therefore 1.4. The colors suggest that this object is a mid–late K spectral type star, depending on the luminosity class (Lang 1992). It is noteworthy that, on the night of February 18, the star underwent a fading in the R band of about 0.5 mag which lasted less than 3 hours, possibly due to an eclipse. The March observations show this object at the B and R values outside the fading phase. The magnitudes obtained from the Palomar Sky Survey and from our frames then seem to indicate that this star might be a binary red dwarf which undergoes eclipses.

Finally, we noticed that in the DSS frame an extended feature is present at $\alpha = 15^{\rm h}\ 28^{\rm m}\ 32^{\rm s}$; $\delta = +19^\circ\ 39'\ 09''$ ($\pm 5''$; equinox 2000.0). This feature is missing both in all our frames and in B and R Palomar Sky Survey plates. We suggest that this 'ghost object' might be an error in the digitalization of the Palomar plates.

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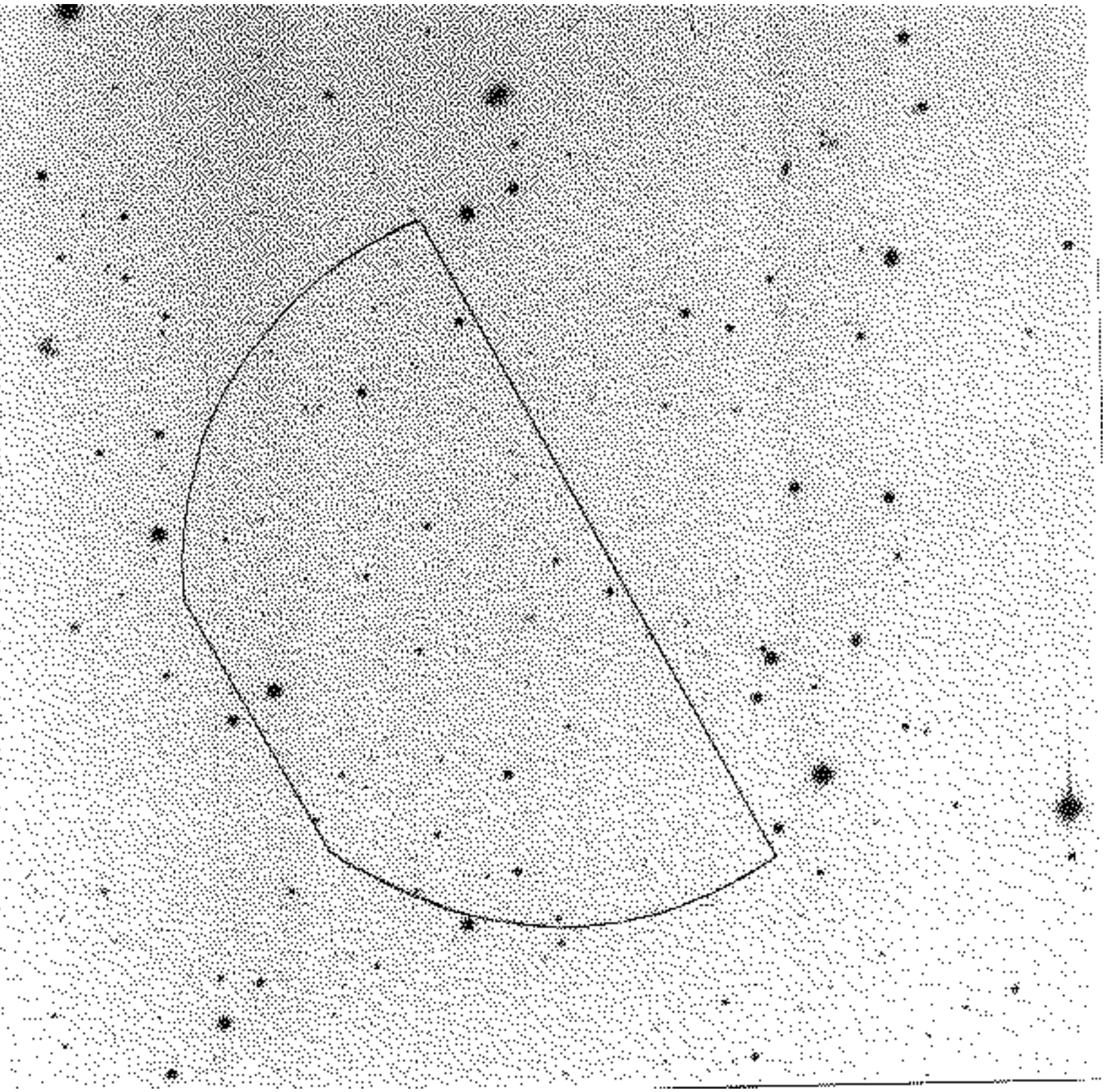

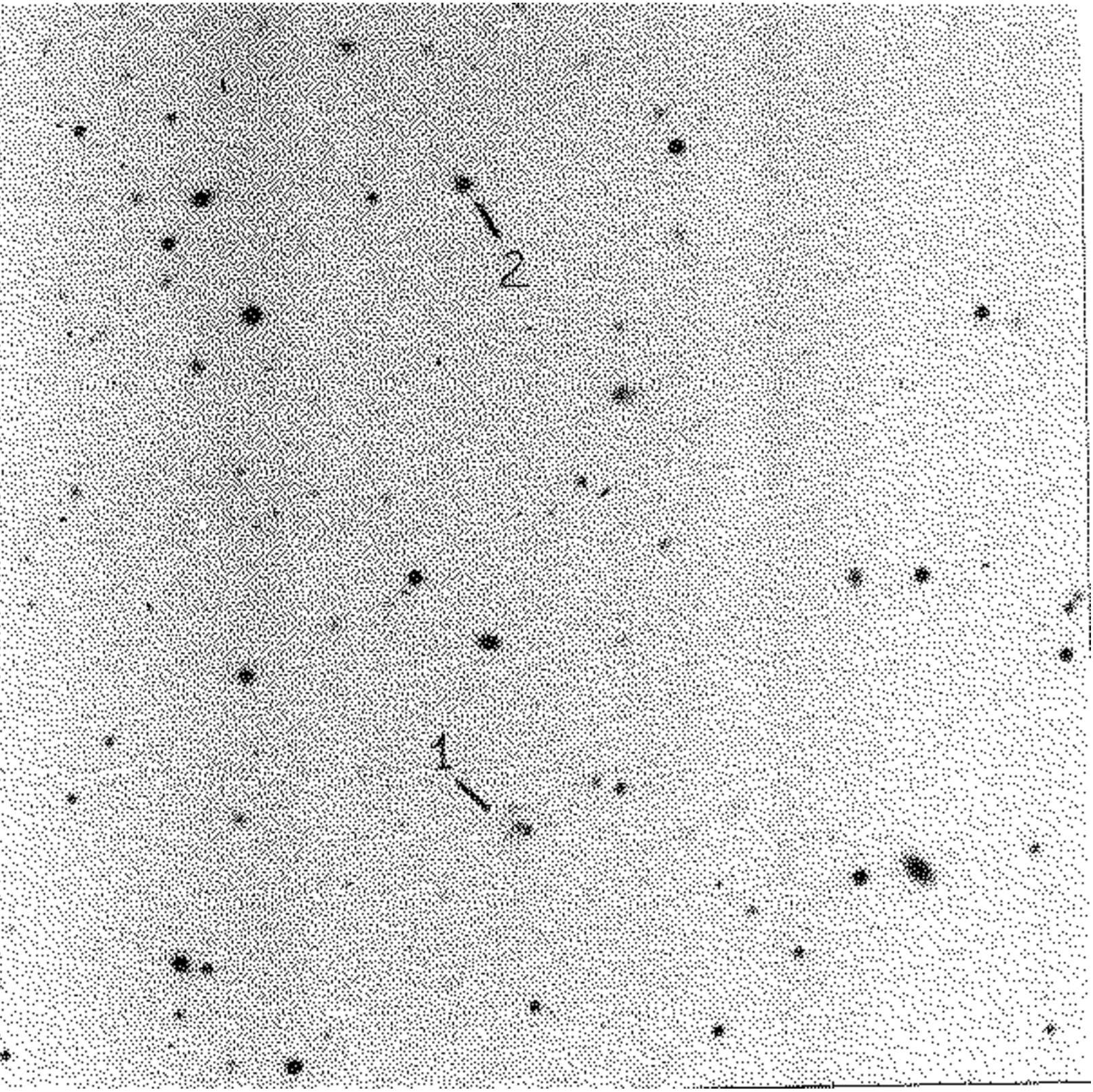
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